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Role of Titab Reservoir in Sustainable Irrigation Requirements in Downstream Saba Watershed

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Abstract. The Saba watershed is the main water source for irrigation areas downstream of the Saba river. The Titab Reservoir was built to be able to meet the continuity of irrigation water supply, especially during the dry season. This study aims to analyze the fulfillment of irrigation water requirements provided by the Titab reservoir. The study began by collecting data first, in the form of primary and secondary data. Primary data is used to see the existing conditions. Secondary data is used for irrigation requirements analysis and simulation. The secondary data used for manual calculations are 15 daily rainfall data, 15 daily measured discharge, and climate data for 10 years from 2006-2016. The output of these data is the need for irrigation water, the potential evaporation, and the discharge reliability used for the simulation. The simulation was carried out using the RIBASIM 7.01.24 program by entering the calculated data and the existing reservoir data. The simulation results show that the irrigation water needs supplied in each irrigation area are not sufficient according to the plan and the reservoir reliability value is low, namely 57.35%.

Keywords. Irrigation, Reservoir, Watershed

1 Introduction

The Saba watershed is one of the watersheds in Bali with an area of 69.54 km2 and the drainage length is about 36 km. Saba River is a cross-district river whose drainage area covers Tabanan Regency and Buleleng Regency. The discharge of the Saba river is permanent and quite large throughout the year. The sources of surface water available for the Buleleng and surrounding areas mostly come from the Saba river. The watershed of the Saba river is a hilly area. This causes rainwater to quickly flow into surface runoff. The rainwater then flows into the river into floods that come quickly and recede quickly as well. The condition of the land in the inundation area generally consists of paddy fields that depend on rain, there is no technical irrigation system so the cropping pattern depends on the rain. In the rainy season, the type of crop planted is paddy, while in the dry season the type of crop is generally secondary crops. Agricultural productivity is generally low with the type of paddy plant at 3-4 tons/hectare. The Titab Reservoir was built to strengthen the program in an integrated manner and preserve water resources and the environment. The construction of the Titab Reservoir is expected to meet the continuity of irrigation water supply, especially during the dry season.

Titab Reservoir is one of the largest reservoirs in Bali. The location of the Titab Reservoir is administratively included in five village areas: Telaga Village, Busungbiu Village, Busungbiu District, and Ularan Village and Village Ringdikit in Seririt District, Buleleng Regency. Titab Reservoir serves as a provider of irrigation water for the Saba area of 1,396.40 ha and Puluran covering an area of 398.42 ha. Titab Reservoir with an effective storage capacity of 10 million m3. There are two irrigation dams in the downstream Titab reservoir, that are the Saba and the Puluran weir. These two weirs will be supplied for irrigation needs from the Titab Reservoir. Based on the role of the Titab Reservoir which is quite large in the development of water resources in the Saba watershed, it is necessary to analyze whether the water capacity provided by the reservoir can meet irrigation needs. The analysis will be carried out using manual calculations and simulations using the RIBASIM 7.01.24 program.

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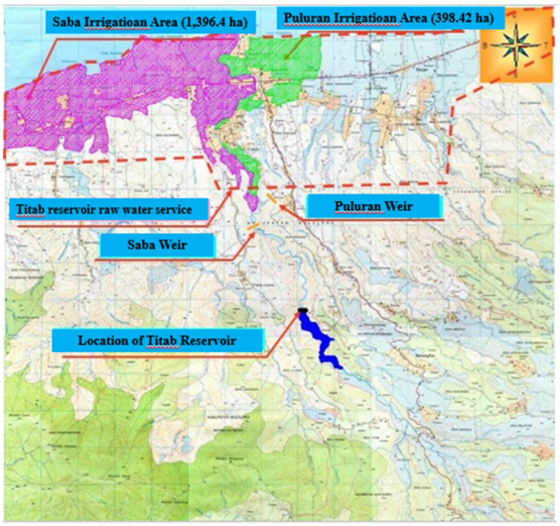

Fig. 1. Location of Titab Reservoir

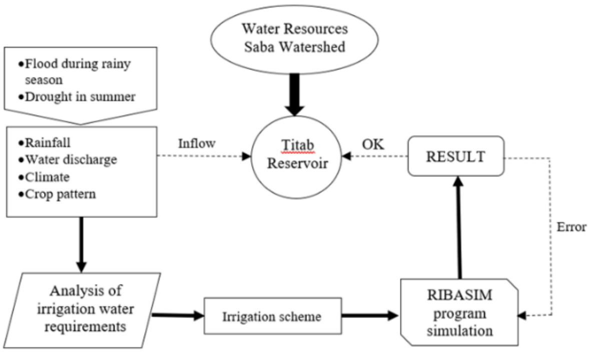

Fig. 2. Frames Work

2 Methods

This research begins by looking for primary and secondary data. Primary data were obtained from the results of field surveys in the Titab reservoir and the irrigation area that will be fed by water from the Titab reservoir. Secondary data were obtained from related agencies or institutions. The secondary data obtained are rainfall, measured discharge, Saba watershed maps, Titab reservoir location maps, Titab reservoir technical, climate, irrigation schemes, raw water, cropping patterns, and reservoir inundation curves. The data were then analyzed manually and simulated using the RIBASIM 7.01.24 program. Analysis can be calculated by the following method..

2.1 Reliability Discharge

The analysis begins with calculating the mainstay discharge based on the daily measured discharge for 10 years 2007-2016. The mainstay discharge is the minimum river flow with a certain amount that has the possibility of being fulfilled [1] which can be used for various purposes [2]. The mainstay discharge is determined by ranking statistical method using frequency or probability analysis known as the Weibull equation [3].

$$P = \frac{m}{n+1} x\ 100\% \qquad (1)$$

The probability of the reliability discharge [4] in question is related to the probability or value of the possibility of its occurrence being equal to or exceeding the expected. The mainstay discharge used for planning the provision of irrigation water uses a reliable discharge of 85% [5].

2.2 Effective Rainfall

Effective rainfall is needed to calculate irrigation water needs in an irrigation area [6]. Effective rainfall is calculated based on 15 daily rainfall data for 10 years 2007-2016. Determination of effective rainfall [7] is based on monthly rainfall, which uses R80 [8], which means that there is a 20% chance that it will not occur [9]. Effective rainfall can be calculated by the following formula below [10].

$$\text{Re} = 0{,}7\ \text{x} \frac{1}{15} (R_{80}) \text{for paddy} \qquad (2)$$

$$\text{Re} = 0{,}5\ x \frac{1}{15} (R_{80}) for\ palawija \qquad (3)$$

2.3 Reference Evapotranspiration (ET_0)

Reference evaporation (ET_0) value can be calculated from meteorological data [11]. The formula that accurately describes the reference evapotranspiration is the Penman-Monteith formula [12]. In 1990 the formula was modified by FAO and developed into the FAO Penman-Monteith formula [13] which is described as follows below.

$$ET_0 = \frac{0{,}408\Delta(Rn - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)} \qquad (4)$$

2.4 Irrigation Water Requirements

Most of the irrigation water requirements are met from surface water [14]. The need for irrigation water is influenced by various factors such as climatology, soil conditions, crop coefficients, cropping patterns, water supply provided, irrigation area, class system, planting schedule, and others. Irrigation needs are calculated [15] by the following equation.

$$IWR = \frac{(ETC + IR + WLR + P - Re)}{IE} \times A \qquad (5)$$

2.5 RIBASIM Program 7.01.24

The RIBASIM 7.01.24 program is one of the water allocation models that can be used at the planning stage of water resources development [16], as well as operationally to assist tactical decision making (eg as a means of negotiating reservoir operations or granting industrial water extraction permits). In this research, RIBASIM 7.01.24 program is used to analyze the water balance in a basin or river that will be simulated [17]. The final result of RIBASIM 7.01.24 can provide basic information about the availability or quantity of water at each location at any time in the river basin.

3 Results and Discussions

3.1 Calculation of Irrigation Requirements

The first analysis calculates the 85% reliable discharge with equation (1) based on 15 daily measured discharge data. From this equation, the value of Q85 the average is 1.47 m3/sec, Q85 maximum 2.27 m3/sec, and Q85 minimum 0.70 m3/sec. The reliability discharge value of 85% can be seen in the image below.

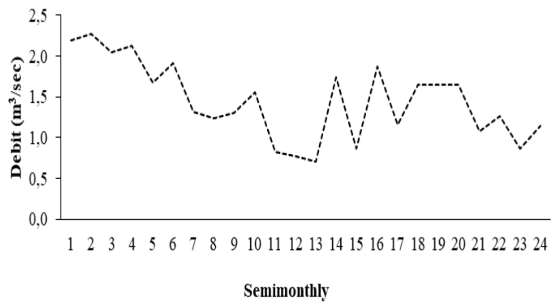

Fig. 3. The discharge graph of the 85% reliability of the Saba watershed

The next analysis is to calculate the effective rainfall of paddy and secondary crops to determine the amount of irrigation water needed. Calculation of effective rainfall is carried out using the formula in equations (2) and (3). The calculation results are obtained as shown in the table below.

Table 1. The scenario of cropping patterns and irrigation water requirements for each scenario

Irrigation Area	Cropping Pattern (Paddy - Paddy - Palawija)	Irrigation Water Requirements in a year (10^6 m^3)
Puluran	In early October (CP1)	7.49
	In mid-October (CP2)	7.25
	In early November (CP3)	8.05
	In mid-November (CP4)	7.98
	In early December (CP5)	7.68
	In mid-December (CP6)	7.87
Saba	In early October (CP1)	26.24
	In mid-October (CP2)	25.40
	In early November (CP3)	28.22
	In mid-November (CP4)	27.98
	In early December (CP5)	26.91
	In mid-December (CP6)	27.57

The scenario above will be used in the RIBASIM simulation to find out the most effective cropping pattern with an optimal level of reliability.

3.2 Simulation RIBASIM 7.01.24

First, before starting the simulation, it is necessary to create a scenario. This study will only discuss the utilization of the Titab reservoir for irrigation needs. Two scenarios will be simulated in the RIBASIM program.

Scenario 1: the situation before the construction of the Titab reservoir with the Paddy-Paddy-Palawija cropping pattern.
Scenario 2: the situation after the construction of the Titab reservoir with a Paddy-Paddy-Palawija cropping pattern.

Next, create an irrigation network scheme downstream of the Saba watershed with the boundaries as shown in the image below. And then input the physical data of the reservoir and irrigation needs into the RIBASIM program. Based on the simulation results, the amount of irrigation water needs that are met in each irrigation area is as follows.

Table 2. Irrigation water requirement after simulation

Irrigation Area	Cropping Pattern (Paddy - Paddy - Palawija)	Irrigation Water Requirements in a year (10^6 m^3)	Irrigation Water Requirements in a year (10^6 m^3)	
			Scenario 1	Scenario 2
Puluran	In early October (CP1)	7.49	4.99	5.18
	In mid-October (CP2)	7.25	4.85	4.99
	In early November (CP3)	8.05	5.12	5.22
	In mid-November (CP4)	7.98	5.24	5.51
	In early December (CP5)	7.68	4.95	5.09
	In mid-December (CP6)	7.87	5.3	5.33
Saba	In early October (CP1)	26.24	16.81	17.86
	In mid-October (CP2)	25.40	16.38	17.21
	In early November (CP3)	28.22	17.21	17.89
	In mid-November (CP4)	27.98	17.59	18.97
	In early December (CP5)	26.91	16.58	17.45
	In mid-December (CP6)	27.57	17.83	18.32

Table 3. Summary of Saba irrigation area simulation results

Scenario 1	CP1	CP2	CP3	CP4	CP5	CP6
Supply (m^3/sec)	1.61	1.57	1.65	1.70	1.59	1.72
Demand (m^3/sec)	2.32	2.16	2.40	2.46	2.36	2.48
Shortage (m^3/sec)	0.71	0.59	0.75	0.76	0.76	0.77
Scenario 2	CP1	CP2	CP3	CP4	CP5	CP6
Supply (m^3/sec)	1.71	1.65	1.72	1.77	1.68	1.76
Demand (m^3/sec)	2.32	2.16	2.40	2.46	2.36	2.48
Shortage (m^3/sec)	0.61	0.52	0.68	0.69	1.08	0.72

Table 4. Summary of Puluran irrigation area simulation results

Scenario 1	CP1	CP2	CP3	CP4	CP5	CP6
Supply (m^3/sec)	0.48	0.46	0.49	0.51	0.48	0.51
Demand (m^3/sec)	0.66	0.62	0.68	0.70	0.67	0.71
Shortage (m^3/sec)	0.18	0.15	0.19	0.20	0.20	0.20
Scenario 2	CP1	CP2	CP3	CP4	CP5	CP6
Supply (m^3/sec)	0.50	0.48	0.50	0.52	0.49	0.51
Demand (m^3/sec)	0.66	0.62	0.68	0.70	0.67	0.71
Shortage (m^3/sec)	0.17	0.14	0.18	0.19	0.18	0.20

Table 2 shows that the construction of the Titab reservoir has not been able to meet the water needs in the region irrigation areas of Saba and Puluran. This can be seen from the value of irrigation water needs that can be met during the simulation of each scenario, which is less than the expected irrigation needs. In addition, the average reservoir reliability value for scenario 2 is 57.35%. While the reliability of the reservoir is expected to be 80%. Tables 3 and 4 also show the same thing, the need is greater than the available water.

4 Conclusion

The simulation results of the RIBASIM 7.01.24 program obtained that the value of irrigation water needs in scenario 1 and scenario 2 did not meet. The reliability value of the reservoir is 57.35%, which is still far from the reliability of the planning reservoir. This shows that the irrigation water needs in the irrigation areas of Saba and Puluran have not been optimally met with the construction of the Titab reservoir. So, there is a need for a re-analysis to see the role of the Titab reservoir in the development of water resources in the Saba watershed, especially in meeting irrigation needs. In future research, it can analysis using a different cropping pattern with rainfall data and daily measured discharge as a comparison.

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